Using NASA Earth-observing Satellites to Help Improve Agriculture and Water Usage
High School

"Water for Wheaties?" Lesson Plan

Lesson Overview:
Students will learn about Earth's freshwater resources and how NASA's Earth observing satellites are helping us better understand Earth's water. They will work in small "expert groups" to explore growing wheat, the differences in weather and climate in two wheat farming regions of the world, Pakistan and Kansas, and the scarcity of freshwater resources in Pakistan. Using this information, students will get into "teams" and work with NASA data from the GPM (Global Precipitation Measurement) mission to explore the amount of precipitation that has fallen in these two regions over the past two decades. They will make recommendations for how farmers in Pakistan could reduce their water usage based on the work that is being done by Faisal Hossain. They will also learn how GPM data is being used to provide micro-insurance policies to small farmers in developing countries to help ensure they will recover their losses in case of extreme drought or flooding. Finally, they will consider ways they can reduce their use of freshwater resources in their own lives.

Time Required: This lesson can take from three to four 45-minute class periods, depending on how in depth the teacher decides to get into the data analysis part of the lesson and how many of the extension activities are included.

NGSS:
This lesson will introduce, reinforce, or give additional content information to support the following HS level NGSS:

- **HS-PS4-5.** Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- **HS-LS1-5.** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
- **HS-LS1-7.** Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

- **HS-LS2-1.** Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- **HS-LS2-2.** Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- **HS-LS2-6.** Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- **HS-LS2-8.** Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce.
- **HS-ESS2-2.** Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
- **HS-ESS2-4.** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- **HS-ESS3-1.** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.
- **HS-ESS3-2.** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
- **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Background Information:
NASA has many Earth observing satellites that are studying Earth's systems. You can learn more about these missions here. The GPM (Global Precipitation Measurement) mission is a NASA mission that is measuring Earth's precipitation around the world. The data from this mission is being used in a wide variety of ways, from helping weather forecasters better predict hurricanes to responding to natural disasters to improving health around the world. In this lesson, we will focus on how GPM data are being used by Faisal Hossain to help wheat farmers reduce their use of precious freshwater resources. They will learn about the work he does as a Professor of Civil and Environmental Engineering, and learn more about his STEM-related career. They will also learn about the work being done by Iker Llabres, who develops

micro-insurance policies to assist small farmers and other small businesses and individuals whose livelihood is impacted by extremes in precipitation.

Materials:
Engage-
For the whole class-
- Plastic world globe
- Clear plastic cup
- Water in a larger container to pour into the cup
- Eyedropper/pipette

"Water for Wheaties?" PowerPoint presentation

Explore:
"Water for Wheaties?" PowerPoint presentation

Explain:
"Water for Wheaties?" PowerPoint presentation
GPM Precipitation Data to Compare/Contrast resource sheet to use in Project Teams

Copies of the Expert Group resource sheets below for each member of the "Expert Group". It will work best if students have access to these documents online with internet connectivity as there are some hyperlinks which lead to short videos in some Expert resource sheets. If this is not available, perhaps the students can watch the short videos on a computer.

"Expert Group" Student Resource Sheets-
- Growing Wheat
- Weather and Climate in Sargodha, Pakistan
- Weather and Climate in Gypsum, Kansas
- Pakistan Freshwater Availability

- Note-Taking Organizer (for each student to use in Expert Group)

Optional: a print copy of Interview with Faisal Hossain (You may decide to have students read this on the projector as a group, or have each student have their own copy.)

Optional: a print copy of Interview with Iker Llabres (You may decide to have students read this on the projector as a group, or have each student have their own copy.)

Evaluate:
"Water for Wheaties?" PowerPoint presentation

Water for Wheaties rubric: one copy for each student or small group (Teacher can decide if evaluation projects will be completed by individual students or in small groups.) The teacher should review the rubric and consider what types of projects (posters, PPT presentations, comics, skits, video product, etc. using a Universal Design for Learning approach)

Extend:
"Water for Wheaties?" PowerPoint presentation

Engage:
The purpose of the activities in this section are to begin to make students aware of the need for freshwater resources for agriculture. They begin by framing the focus of this lesson on being able to learn how technology is enabling wheat farmers in water scarce Pakistan reduce the amount freshwater needed to irrigate their wheat crops. They will review a model which illustrates how photosynthesis transforms light energy into stored chemical energy.

Key Information: Farmers need freshwater resources to grow wheat. Plants use photosynthesis to transforms light energy into stored chemical energy. Earth's water cycle provides the water resources necessary for wheat production. Energy from the sun is used to create the energy that is found in wheat crops. That energy is then transferred to us when we eat wheat products in a process known as "cellular respiration".

Use the information on slide 2 to frame the purpose of this lesson. Slide 3 shows different products that use wheat as a key ingredient.

As an activator, have students brainstorm in a pair/share activity what farmers need to have in order to grow wheat. (slide 4)

Discuss the needs of these crops to have both sun and water. Review the processes that are involved in "photosynthesis". (slide 5) After they have reviewed the process of photosynthesis, watch this short video (02:45) on slide 6 which describes the process of photosynthesis and explains how NASA satellites are able to measure what is happening inside plants on a cellular level. You can click on the picture to open the link. To ensure the video plays smoothly, you might want to have it downloaded ahead of time. On slide 7, the diagram focuses on understanding the process that takes place during cellular respiration to reinforce their ability to "*Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of* *food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy*."

If you think the students could use a quick review of the water cycle to ensure they understand the importance of precipitation for wheat farmers, you can show them the short water cycle animation (2:59- it has no narration) on slide 8. You will click on the picture to open the link that has the animation. You might want to download it ahead of time so it plays fluidly. Help them to name the different processes that are interacting as water moves through the water cycle. Have them identify the processes that include transpiration, evaporation, condensation, crystallization, and precipitation. Emphasize the ways that water changes its state as it moves through the multiple pathways of the hydrologic cycle.

Key Information: Most of Earth's water is salt water. Less than 2.5% of Earth's water is freshwater. Describe and view graphs to understand the amounts and percentages of water and fresh water in various reservoirs on Earth. Farmers use freshwater resources to water their crops. Water is a natural resource that is not renewable. It is unequally distributed around the world.

Look at a globe and ask how much of Earth's surface is covered by water. Do the Globe activity to predict how much of Earth is covered by water. (slide 9)

Watch the video, "Show Me the Water". (slide 10) Click on the picture to open the link. You might want to upload the video ahead of time to ensure it plays smoothly.

Use the bar graph on slide 11 to help students unpack the concepts of where the Earth's water is located. Ensure that they understand how little of Earth's water is actually freshwater. Help them identify the possible water sources on these bar graphs that would be used by farmers to water their crops. Examples of this would include groundwater if they use wells, surface water, atmospheric water (precipitation), rivers, and lakes.

Discuss the questions on slide 12 to help frame students' understanding about the usage of freshwater resources by farmers around the world. Guide students to compare and contrast how much water is used by developing countries and the U.S. for agriculture usage (developing countries- about 70% compared to US about 31 %) as well as the difference between irrigating crops and allowing precipitation to water them. This will be reinforced later as well.

Read the article, "Precious Freshness" and use the information to answer the questions as a class on slide 13. The class can read this article as a class or students can have paper copies (or read electronically on their own).

Explore:
Now the students will begin to think more specifically about the ways in which freshwater resources are used around the world. They will begin to learn about wheat and its importance in our diet. Before they begin their "Expert Group" research, they will also learn the difference between having precipitation water crops and needing to irrigate the crops when there isn't adequate precipitation.

Key Information: Famers sometimes water crops by irrigating versus having them watered by precipitation. Wheat is an essential food across the world. Wheat farmers need to increase crop production to meet the needs of a growing population.

Help guide the students to understand the difference between having crops irrigated versus having enough precipitation to water them adequately. (slide 14)

Introduce the map on slide 15 that shows the major wheat producing locations around the world. Use the information on slide 16 to have them consider issues that wheat farmers will face to meet the needs of the growing population.

Explain:
Now the students have some common background information and are ready to start working in their "Expert Groups". Divide the class into four small groups, each of whom will be responsible for becoming experts on one of these topics. It will work best if they have digital access to the resources below as there are many embedded hyperlinks. Some of these hyperlinks have video files.

- Growing Wheat
- Weather and Climate in Sargodha, Pakistan
- Weather and Climate in Gypsum, Kansas
- Pakistan Freshwater Availability

Have each student take notes on the Note-Taking Organizer to help them have notes to refer to when they get together in their Project Team. Each Project Team will consist of an expert from each group- and thus will be composed of 4 students.

A copy of the GPM Precipitation Data to Compare/Contrast for each Project Team (This will be much more meaningful if it can be printed in color. One for the team of four should be fine)

Key Information: Understand the purpose of the Expert Groups and Project Teams.

Explain to the students that they will work in smaller "Expert Groups" in order to become knowledgeable about one topic. This is how scientists and engineers work when they are working collaboratively on a project. They have different areas of expertise and get together in their "working groups" to build their common knowledge. (slide 17)

For this activity, they will focus on two different wheat growing regions in the world. One of these is in Kansas and the other is in Pakistan, which is a developing country. (slide 18)

After they work with their Expert Group and take notes and discuss their topic, they will assemble into different Project Teams. (slide 19)

Students will review the questions that they will be focusing on within each expert group to get a feel for the broader picture. (slide 20)

Key Information: NASA has a satellite mission that measures global precipitation. GPM uses technological instruments which use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

The Global Precipitation Measurement (GPM) mission is a NASA satellite mission that is able to measure the precipitation as it falls from the clouds to the ground. (slide 21)

Have students learn about the GPM mission by watching "The Data Downpour" and how the data is sent from the constellation of satellites to Earth. This video covers the way in which this data is processed and used for real-world applications. Clicking on the image will open the link that has the video. The video is 4:17 minutes long, and will play more smoothly if you have it open and ready to go or download it ahead of time. (slide 22)

Key Information: Unpacking data from GPM to answer questions in Project Teams

Give the students the directions for what they will do when they break into "Project Teams". These will be small teams of 4, which will include an expert from the different teams in order to be able to share their collective expertise as they attempt to answer a few key questions while looking at GPM data. (slide 23)

Take a minute to review the two locations that they will be looking at GPM's precipitation data to try to determine whether there is enough precipitation to water the wheat crops during each location's wheat growing season, or if they will also need to use irrigation methods. (slide 24)

The data that students are looking at is what is known as "IMERG" data. IMERG data is composed of precipitation estimates from combining microwave data from the

GMI, TMI, and other partner instruments. You can learn more about this data here. If you should want to find the IMERG monthly data for your school location, you can follow the directions here and obtain that data. That might be an interesting activity to do with the class after they have looked at the IMERG data for the two locations we are working with in this lesson.

Assign one member of each Expert Group to a Project Team, which will result in many small Project Teams with 4 members in each team. Allow them a few minutes to look over the data in their Project Team. You may want to consider using these data analysis resources from *My NASA Data* with your students to help them unpack what they are looking at with the interannual time series data graphs. If you have time, preparing the graph cubes ahead of time will enable students to interact with the graphs and help them to unpack the information in a more constructivist manner. There are accompanying student capture sheets that are scaffolded and thus ensure that all students can access the content (Universal Design for Learning).

After they have had enough time to begin to unpack the graphs, use slides 25 and 26 to ensure they are able to do the following:

- Understand that time is being shown on the x-axis using different colored lines. Each line represents a season- “DJF- December, January, February” and so on.
- Understand that the y-axis is showing how much precipitation was measured in *mm* per month (or estimated as it is using remotely sensed data).

Leave the questions on slide 23 and circulate to assist Project Teams as necessary.

They may find that using highlighters is helpful to figure out which data to look at for each location. For example, wheat growing season in Kansas (this information is in the Weather and Climate in Gypsum, Kansas resource) is fairly long. Wheat is planted in the fall, becomes dormant in the winter, and grows in the spring and is harvested in June and July. Thus, the growing season is longer, but the most water will be needed during the spring and early summer. The students could use their highlighters and find the lines that show MAM (March-April-May) as well as JJA (June-July-August). It will not be possible to be exact with this data, but they can be looking for patterns and trends in the data. They may also need some assistance in finding and highlighting the important information that they will need to help them answer their Project Team questions as they look through their Expert Group resources.

They will also need to convert the mm units to cm units- easy enough with the metric system as they just divide by 10- to see if there is enough precipitation to grow wheat without needing to use other water to irrigate the wheat crops. (from the "Growing Wheat" resource- they will note that growing wheat requires between 31-38 cm of precipitation, which will be 310 -380 mm)

From time to time, you may want to use slides 25 and 26 to point out important information or have students assist others in interpreting the data.

Once students have had time to work in their Project Teams and you determine it is time to come together as a class and share in their answers, bring the class back together to answer the questions on slide 27 together. Help them use argumentation strategies to come to a class consensus on the answers.

Key Information- Technology can be used to reduce the amount of freshwater resources needed in Pakistan for growing wheat.

Now students are ready to use what they have learned to consider some possible ways in which technologies could be used to solve a real-world problem, that of limited freshwater resources in Pakistan. Help them to begin this process by showing them slide 28 and having them brainstorm what is happening in this picture.

After they have thought about what was happening in the first picture, show them slide 29 as it will give them additional information to use to try to figure out how

Key Information- Meet Faisal Hossain and learn about his STEM-related career

Faisal Hossain is a professor who teaches civil and environmental engineering at the University of Washington in Washington state. He uses the data from GPM and other NASA satellite missions to help wheat farmers in Pakistan. The farmers get text messages every day letting them know whether or not they should water their wheat crops. He will introduce himself in a short video on slide 30.

Slide 31 includes a quote from Faisal Hossain about the work he is doing with NASA data. After the students have had this chance to get a little background information about him and his work, have students read about his work in the resource, Interview with Faisal Hossain on slide 32. You can show this document on the large screen and/or have each student have their own printed copy.

When they finish, use the diagram on slide 33 to help students see the model that is being used by Faisal Hossain in his work with wheat farmers. Ask for students to explain how this use of technology is helping farmers to reduce their use of freshwater. See if they can list some benefits and also some challenges for this use of technology with the wheat farmers.

Here are some resources to learn more about the work Faisal is doing to reduce the use of freshwater resources using technology. These videos are long, but you might find portions of this information useful for yourself and your students.

- Growing More with Less: Smart Tech Solutions to Feed the World (video presentation by Faisal Hossain)
- Professor Faisal Hossain modernizes irrigation to feed the masses (article from The Daily with many links to more information)
- A collection of videos by Faisal Hossain
- Satellite Data Empowers Farmers in India (additional information about how this program is also being used with farmers in India)

Key Information: Microinsurance is available for subsistence farmers. This insurance is inexpensive as uses GPM data to determine if an extreme event, such a flooding or drought, has occurred and cuts out the need for the middleman.

Students will now consider one more use of technology to assist small farmers when there are extreme weather events which threaten their very livelihood. GPM data is being used to also assist small farmers and other small business owners to afford micro-insurance. Unexpected shocks from natural hazards can affect populations throughout the globe, threatening sustainable development and resilience. However, the impacts of these events such as extreme precipitation or drought disproportionately affects the developing world where individuals often are not insured and live and work in conditions that leave them vulnerable to natural disasters. This can lead to significant economic and environmental challenges if preventive measures or mitigating measures are not taken in time. To reduce risks from natural disasters and build climate resilience, decision makers are using NASA Earth observations to develop index-based insurance products and protect low-income customers in Central America.

An example of this is a company called MiCRO. The Microinsurance Catastrophe Risk Organization (MiCRO) is a reinsurer that specializes in design and implementation of innovative, holistic, affordable and sustainable risk management solutions against natural disasters for the most vulnerable populations. MiCRO's approach is based on a technology platform that provide risk management solutions to deliver tailor-made insurance policies. These policies are designed to protect vulnerable individuals (e.g. subsistence farmers) and small and micro-entrepreneurs against various perils such as excessive rainfall, severe drought, and earthquakes using a pre-determined index (e.g. threshold) that is correlated to direct and indirect losses in a given region. These indices such a precipitation can be monitored using NASA satellites and provide cost-effective and efficient way to capture weather-related parameters like droughts, especially where ground data is sparse. Access to historical and real-time data, such as precipitation data from NASA GPM, has

enabled MiCRO to create their index in order to approximate actual damages and issue claim payouts when precipitation (or other extreme weather events) falls above or below the corresponding threshold in a given region.
On slide 34, there are some guiding questions to help students consider how small farmers might be impacted when an extreme weather event destroys their crop. Slide 35 helps them think about the use of insurance for small farming operations. Students are introduced to the use of microinsurance on slide 36. Slide 37 gives more information about the use of microinsurance for farmers and for other small business owners. On slide 38, there is a diagram showing the model by which this microinsurance is determined and how clients receive their payouts. On slide 39, Iker Llabres, an actuary who specializes in this type of microinsurance, called "index" insurance, answers a few questions about his work in a short video. On slide 40, there is a link to open a print interview with Iker Llabres to learn more about his work, the kind of education he needed to get his job, and how he uses NASA data to do his work. Student could receive a print copy or read this two-page document online. There is more information in an article here entitled "*Building Climate Resilience with Satellite Data*".

Evaluate:

Key Information: Understand that most careers require us to communicate our findings to others. This is true for scientists and engineers as well.

Help students to understand that most careers require that people have a way to communicate what they learn to others. This is true for scientists and engineers as well. Use slide 41 to review the scientific research process and see where "Present Findings" falls within the scientific research process.

Key Information: Understand the expectations for the project

Use slide 42 to frame the expectations for the content the students will include in their final project. This could be completed as an in class or homework assignment. Based on the needs of your students and your classroom environment, you can determine whether the projects will be completed individually or in small groups. The rubric is based on a final product being a brochure, and includes assessment in these areas: writing- ideas, writing- sentence fluency, Media- graphics, Design- layout and organization, Planning- rough draft. The teacher may modify this rubric to meet the unique needs of their learners, curriculum, and types of presentations that appropriate for their learners.

Elaborate/Extend:

Key Information- NASA Earth observing missions help us understand our home planet

Click on the image on slide 43 to open the link that has a short video entitled "Why Does NASA Study Earth?". This video is very short (1:52) and uses drawings to explain why and how NASA Earth observing satellites help us learn about Earth.

Key Information: Saving Freshwater Resources
Slide 44 has a link to the EPA's "WaterSense" website with activities and information for students and teachers.

Show students slide 45 and have them brainstorm on the question.
Have them read "Earth's Water Delivery:? No Passport Required" to learn more about Earth's freshwater resources and how they are inequitably distributed around the world. Students could have their own copies or read the article as a class on the projector screen.

Additional Resources:
There are more resources you and the students might want to explore on slide 46 and slide 47. You may also want to explore the resources in GPM's "Precipitation Education" website, as there are a rich array of educational resources on this website.

Students can explore climate classification systems using this GLOBE "What is Your Climate Classification?" activity.

The Smithsonian has a fantastic curriculum entitled *Food!* This is a freely available community research guide developed by the Smithsonian Science Education Center (SSEC) in partnership with the InterAcademy Partnership as part of the Smithsonian Science for Global Goals project. These Smithsonian Science for Global Goals community research guides use the United Nations Sustainable Development Goals (SDGs) as a framework to focus on sustainable actions that are defined and implemented by students.

Credits:
Special thanks to Faisal Hossain and the "Pakistan Council of Research in Water Resources" (http://www.pcrwr.gov.pk) for contributing to this work as well as to Iker Llabres and the MiCRO organization.